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COMBAT VEHICLE TEST BEDS:

A STUDY OF THE USE OF TEST BEDS IN THE DEVELOPMENT OF

COMBAT VEHICLES

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This study examines the role of test beds in the development of combat vehicles with particular reference to the current problems created by the rapid advances in combat vehicles and related technologies. Test beds represent the only means by which some of the major aspects of new vehicle concepts can be assessed, both by their developers and by their potential users in a practical and unambiguous way.

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SUMMARY

This study examines the role of test beds in the development of combat vehicles with particular reference to the current problems created by the rapid advances in combat vehicle and related technologies. These advances have raised questions about the direction of future combat vehicle development, and the need to resolve them has made test beds more important than ever.

Test beds are important now because the changes brought about by advancing technology have created both new opportunities in combat vehicle design, and uncertainties about the shape that future vehicles should take. The opportunities need to be fully explored and questions about the configuration of future vehicles need to be resolved.

To respond to these needs rapidly and economically, it is essential to pursue vigorously the design, construction and evaluation of test bed vehicles, which have much to contribute to the development of the next generation of combat vehicles. Test beds represent the only means by which some of the major aspects of new vehicle concepts can be assessed, both by their developers and by their potential users in a practical and unambiguous way. Test beds constitute an important basis for making sound decisions on future combat vehicle programs. Without test beds, decisions might be made without the problems involved in new concepts being fully faced and resolved. This could have damaging, even disastrous consequences for future combat vehicle programs.

CONTENTS

1.0. INTRODUCTION

1.1. Development of combat vehicles is facing a major challenge due to the recent advances in technology. In essence, the challenge is how best to respond to these advances which, on one hand, have increased considerably the threats facing combat vehicles and, on the other hand, have created new development opportunities.

1.2. The overall effect of the advances in technology has been to make the development of combat vehicles more difficult. Many of the basic, long accepted features of combat vehicles can no longer be taken for granted, because of the new and more varied threats to which they are now exposed and because of the different vehicle configurations which are now possible. As a result, there are uncertainties about the direction that the development of future combat vehicles should take. This applies especially to the configuration of future tanks, or tank-like vehicles. There is a need for a new design in view of the increasing lethality and changing nature of the threats facing tanks. This need is reinforced by such fields as automation and electro-optics.

1.3. To explore and to assess new ideas and design concepts requires the construction and evaluation of test bed vehicles. Test beds, already important in the development of combat vheicles, are the only means of soundly resolving the design questions about future combat vehicles and of working economically toward the optimum designs of the next generation of combat vehicles.

2.0. NATURE OF TEST BED VEHICLES

2.1. This section establishes what test beds are. There appears to be no generally recognized definition of them.

2.2. In the context of this report, test beds may be defined as experimental vehicles designed and built to explore new concepts in the configuration of combat vehicles. Unlike prototype vehicles, test beds have no initial commitment in their development program for a follow-on production run of field service vehicles. In contrast, prototoypes are understood to be vehicles built to prove a design based on agreed user requirements, and which is intended from the start to be put into production and service. A practical consequence of the difference between test beds and prototypes is that test beds do not need to be as complete or worked out in the detail required of prototypes. This implies obvious economies in test design and construction. Test beds do not require the setting up of major program management structures, which implies further economies.

2.3. However, if the ideas embodied in test beds prove to be sufficiently promising, the recently constructed test beds may become models for future production vehicles. To this extent test beds may become prototypes or, more correctly, pre-prototypes. For this reason, some vehicles which were basically test beds have been called prototypes. This has also been done simply because people fail to perceive the differences between the two categories of vehicles. Test bed vehicles have also been called "experimental prototypes", which at least draws a distinction between them and prototypes proper, or simply "experimental vehicles", which avoids the the confusion with prototypes but is not sufficiently explicit (1).

2.4. A further difference must also be recognized between test bed vehicles and experimental vehicles used only to test one particular component or sub-system. (The latter are sometimes called "test rigs", although this term has also been applied, particularly by the British, to vehicles which would more appropriately be called test beds.)

2.5. Whatever their designation, the principal purpose of the last category of vehicles is to conduct engineering tests of a new component or sub-system. The sub-system may embody new concepts, but the vehicle in which the testing is conducted does not represent any new concept in the configuration of combat vehicles as a whole. In fact, test rig vehicles of this kind are usually existing vehicles, modified to suit a particular test program. In consequence, their use and importance are generally confined to component development. However, in some cases the component or sub-system may be such that its importance and impact extend well beyond its own tests. In that case the vehicle in which it is installed may assume the character of a combat vehicle test bed. This might be so, for instance, when the component is some radically new form of main armament, such as vertically launched guided missiles or a laser sensor damage system.

3.0. DIFFERENT FORMS OF DEVELOPMENT

3.0.1. Although the basic purpose of test beds may be defined as the exploration of new vehicle configurations, this is only one of several aspects or phases of the development of combat vehicles. It is necessary, therefore, to consider the relationship between test beds and the other aspects or phases of combat vehicle development to determine the importance of test beds to the development of combat vehicles as a whole.

3.1. Component Development

3.1.1. The first different aspect of the development of combat vehicles that needs to be considered is component development. Exploitation of advancing technology produces new and more effective components, which are the essential ingredient of major advances in the design of combat vehicles. Advances in componentry also make it possible to upgrade, in different ways, the capabilities of existing vehicles.

3.1.2. As defined, test bed vehicles have little to contribute directly to the development of components. However, problems or ideas brought out during test bed design and evaluation can lead to the development of new components. They can do so at a much earlier time than that which would come from experience with standard combat vehicles. For instance, evasive maneuver tests carried out in the Federal Republic of Germany in the late sixties with high mobility test beds provided much of the lead to the development of components incorporated in the twin-gun casemate VT-1 test beds built in West Germany in the seventies.

3.1.3. Experimental vehicles can contribute directly to the development of components and have done so many times. But in that case they only need to have the characteristics of what has been described as test rigs and not those of test beds, as defined earlier.

3.2. Product Improvement Programs

3.2.1. Another major aspect of the development of combat vehicles is product improvement programs. Essentially they take advantage of advances in technology to improve vehicles already in service or those being produced by installing more effective components or sub-systems than those originaly installed or specified.

3.2.2. By doing this, product improvement programs can extend the effectiveness of particular combat vehicles for several years and thus maintain the effectiveness of combat vehicle fleets without procuring new vehicles. The procurement of new vehicles is more expensive than modifications of vehicles already in service or in production, making product improvement programs very cost effective. Their time span is limited by what can be done to improve any particular vehicle and by the rate of advances in technology which, ultimately, overtake any further product improvements to an existing vehicle and render them unprofitable.

3.2.3. A successful product improvement program is illustrated by the British Centurion battle tank, which was first built in 1945 and was still in service during the 1982 Israeli Lebanon campaign. Its continuing effectiveness during the 37 years of its existence is based on product improvement. The Centurion has been improved progressively: twice refitted with more powerful guns and with more advanced fire control systems; several times with more armor; once with a completely new power pack; and in one case, with a new hydropneumatic suspension (2).

3.2.4. The US M4 medium tank provides an earlier example of extended service life through the introduction of improvements, both during its production and then during its service. The M4 was up-gunned four times (even more than the Centurion) (3). Some M4 tanks still remain in service 40 years after they were first produced. But further improvements to the M4 are not contemplated because component improvement is no longer competitive with recently designed tanks (based on more modern technology).

3.2.5. The latest example of product improvement is provided by the M1 tank. In this case the program to introduce a 120 mm gun in place of the current 10-5 mm gun was initiated two years before the first M1 tank came off the production line. As a result, the improved M1E1 tank will have a much more powerful main armament as well as other improvements to the original M1 version (4).

3.2.6. But, no matter how effective they might be, product improvements do not alter the basic configuration of a combat vehicle. They do not, therefore, require test beds to be designed and built. Instead they require tests to be carried out with modified vehicles prior to the acceptance of the improvements.

3.3. Evolutionary Development

3.3.1. Product improvements reach a point sooner or later where they are no longer sufficiently effective to warrant pursuing. Then it becomes imperative to produce a new design. Evolutionary development, which implies a sequence of progressive, incremental changes (5) has been highly successful. This kind of development eases technical problems, because only part of a combat vehicle design is changed at any one time, and a new vehicle based on it can be introduced into service more quickly and at less risk and cost than one completely redesigned.

3.3.2. The outstanding example of evolutionary development is that of Soviet tank designs, from the T34 into the T62 over a period of 18 years. The first incremental change was the development of the T34/85, which consisted of a new turret with a more powerful, 85 mm gun mounted on a virtually unchanged T34 chassis. The next change was represented by the

T44, which had a new hull, new suspension and a new, transverse engine (but which retained much the same turret and the same gun as the T34/85). This was followed by the T54, which had a new turret with a more powerful 100 mm gun on what was basically a T44 chassis. The T54 and its improved version, the T55, were followed by the T62, which had a larger turret and a new smooth-bore 115 mm gun mounted on a modified T54 chassis (6).

3.3.3. Such a sequence of designs, each representing a partial departure from that preceding it, saved the Soviet Union a great deal of design trouble and effort. It also provided the high degree of continuity essential to the transfer of experience gained from one design to the next. However, its success depended on the absence of any radical changes in tank design during the period of the evolutionary developments. In fact, the basic configuration of tanks remained virtually unchanged during that period, as no major departures from it were practicable. Had it been possible to design radically different vehicles, the course of the development might have been very different. In particular, the change from one design to the next would have been more abrupt, and fewer features and components (or even experience) would have been carried over from one design to the next.

3.3.4. Thus, strictly evolutionary development, such as that of the Soviet tanks from the T34 to the T62, can be effective only for a certain period of time, during which there are no practicable alternatives to the established, basic configuration. This was the case during the past thirty-odd years, but is no longer so. In consequence, more radical advances than those allowed by a strictly evolutionary process have to be considered.

3.3.5. Until now, during strictly evolutionary development, no need for test beds was apparent, because each new design represented only a partial advance on its predecessor. It did not involve any major departure from the basic tank configuration. In other words, it might have appeared that all uncertainties could be resolved by the writing of military requirements and that only prototypes had to be built before a new design was put into production.

3.3.6. In fact, test bed vehicles have proven effective even when the development has been of an evolutionary nature. An early example of this is the series of experimental vehicles which preceded the design of the Soviet T34 in the late thirties. The T34 is generally considered to be an evolutionary development of the earlier, Christie-inspired BT tanks. Moreover, several of the major components incorporated in it, including its 76.2 mm gun and V2 diesel, had all been tried in late models of the BT series. Yet the design of the T34 evolved only after the construction of several experimental vehicles, such as the BT-IS and the T32, which put to test the whole combination of ideas and components subsequently embodied in the T34 (7).

3.3.7. A more recent example of the contribution made by test beds to the evolutionary development of combat vehicles is provided by the current British Chieftain which, in many respects, is a direct descendant of its predecessor, the Centurion. Yet its design was also preceded by the construction of a test bed vehicle, called FV 4202, which put to test some of the novel features subsequently incorporated in the Chieftain (such as the supine driving position and internal gun mantlet) (8).

3.3.8. Without the test beds, the design of the new vehicles could have been much more risky and their subsequent fielding might have been less successful than it was, thus, even when the development of combat vehicles is basically evolutionary in nature, test bed vehicles can be of considerable value because of the opportunities they provide to test and to assess the main features of new designs well in advance of any commitment to them.

3.4. Development of Radically New Designs

3.4.1. If test beds can be of considerable value to the evolutionary development of combat vehicles, when this amounts to more than minor changes from one design to the next, they are indispensable when radically new designs are involved. They are, in fact, the only means available of exploring new design concepts without incurring excessive design costs and risks, and of demonstrating new designs to the user in a practical and early way.

3.4.2. When the new concept is found to be acceptable on both technical and military grounds, test bed vehicles further provide a good basis for any subsequent, full-scale development of a new combat vehicle embodying the concept. In particular, they can free the full-scale development of some of the uncertainties and risks inherent in any new design, because its basic features would have been faced in them already.

3.4.3. On the other hand, if the experience with test bed vehicles leads to the conclusion that a new concept should not be pursued further, it can be abandoned, or shelved, when the amount of money and effort spent on it is still limited, and no loss of prestige or political issues are involved.

3.4.5. The value of test bed vehicles in both circumstances has been demonstrated several times already. One good example of the use of test beds to explore new concepts, and to lay a sound basis for the design and production of a new combat vehicle is provided by the development of the Swedish S-tank (9). In this case a series of low-cost test beds was used to prove the novel features ultimately embodied in the S-tank and they also ensured that only a relatively small amount of money would have been lost had these features proved unworkable or unacceptable.

3.4.6. Another example of the judicious use of test beds to successfully explore new design concepts is provided by the British FV 4211 experimental tank (10). This survivability test bed was the first vehicle to incorporate Chobham special armor in its design. It served to establish that battle tanks with special armor were practicable, without any commitment having to be made at the time to produce and to field such tanks.

3.4.7. In retrospect, it is possible to claim that successful concepts were so promising that they did not require test beds to prove them, and once conceived, they could and should have been put straight into development for production and fielding. However, new concepts are not that easy to assess when they are first put forward. This is demonstrated by the number of concepts which were considered promising at first, but which were not pursued further after the construction of test bed vehicles embodying them.

3.4.8. An early example of this was the series of the experimental battle tanks with trunion-mounted, or oscillating, turrets built during the fifties in the United States as well as France (11). These vehicles offered several advantages over tanks with conventional turrets, but the construction of test bed vehicles brought out serious disadvantages. In consequence, the concept of tanks with oscillating turrets was not pursued beyond the test beds. None of the effort and money which might have been misspent putting such tanks into production was wasted.

3.4.9. A more recent example is provided by the VT-1 vehicles built in the Federal Republic of Germany during the mid-seventies (12). These turretless, or casemate, vehicles with twin 105 or 120 mm guns in semi-fixed mountings represented novel ideas which deserved being explored. In the end they were not accepted for further development, but the construction of the test beds was fully justified. First, they developed the new concepts fully to the stage where they could be properly tested and then demonstrated that they were not worth pursuing, after all.

3.4.10. Test beds have an important role to play in exploration of new concepts whether or not these concepts lead to the production and fielding of new combat vehicles. Whatever the outcome, it is essential to explore new concepts, or there can be no real progress in the design of combat vehicles. In one case test beds were indispensable for proving a concept and laying a sound foundation for further development. In the other case test beds provided a firm basis for concluding that a new concept was not worth putting into production and service. This will happen when researchers thoroughly explore many promising concepts. By providing the basis for such conclusions, test beds can help to avoid the expenditure of more than the necessary minimum of effort and money.

3.5. Flawed Alternative

3.5.1. It might be argued that a superior alternative to the evolutionary development of new combat vehicles (and to exploring new concepts by means of test beds) is to investigate new concepts by means of analytical studies. If these are favorable, researchers then can proceed on the assumption that any new vehicle concept can be put into production given sufficient resources, even when it is necessary to develop the components as well as the whole vehicle (13).

3.5.2. An example of such an alternative is provided by the development during the sixties of the MBT-70. Its design was based on an extensive analytical study carried out by the Lockhead Missiles and Space Company and tank prototypes were designed and built, using newly designed components, without prior investigations using test bed vehicles.

3.5.3. The outcome of the MBT-70 program was unsuccessful. Much of this was due to the faults inherent in the approach adopted to develop the MBT-70. In particular, the analytical model on which its design was based did not anticipate all the practical design problems that arose. The same would apply, even if the analytical modelling were much improved, because many of the inputs on which the model depended to produce solutions were of a historical nature. In consequence, the validity of analytical modelling is severly circumscribed whenever radically new concepts are involved. Exploration of new concepts with test beds is certain to bring out any major new problems that may be hidden. Test beds make it possible to assess new concepts more accurately, and either to attack the problems posed by them at an early stage of the development, or to abandon the concepts if the problems are considered too difficult or too costly to resolve.

3.5.4. The other inherent fault of the approach exemplified by the MBT-70 program was the assumption that, once a new concept was approved on the basis of analytical studies, sufficient resources could always be mobilised to put it into practice. In principle this may be true, but the necessary expenditure of effort and money may be unacceptably high or even unnecessary.

3.5.5. This was clearly demonstrated by the MBT-70 program, which was terminated because Congress concluded that it was becoming too expensive. The MBT-70 program was also termed unnecessarily expensive. Comparing its cost with that of the contemporary development of the S-tank, which in many ways represented a concept as novel as that of the MBT-70, showed the S-tank program to be more austere. The S-tank also judiciously exploited low cost test beds. As a result, it cost $24 million, whereas the expenditure on the MBT-70 at a comparable stage of development escalated to $303 million (14).

4.0. CURRENT NEED FOR TEST BEDS

4.1. It should be evident that test bed vehicles are a valuable means of exploring and assessing new concepts in combat vehicle design. It should also be evident that their value increases with the novelty of concepts or the degree to which such concepts depart from earlier ideas and advance on existing configurations. In consequence, test beds should be of particular value at present when there is a great need to advance on the configurations adhered to for many years and when there is an unprecedented opportunity for doing this.

4.2. The need for major advances arises from several sources. One of them is the level of the threat which is now facing combat vehicles as a result of the progress made in the development of armor-piercing weapons. The capabilities of anti-tank weapons have lead to several changes in the design of combat vehicles. Successive increases in the armor of tanks, (which has grown in recent years to a horizontal thickness of more than 300 mm over the fronts of hulls and turrets) have spurred increases in the weight of tanks. Now weighing more than 50 metric tons, some of the latest designs have come close to the practical armor limit. However, still greater increases in armor protection are required to provide tanks with a reasonably high degree of survivability in the face of guns firing current armor-piercing projectiles or missiles with advanced shaped charge warheads. But the required increases in armor protection can not be achieved without departing from the standard configuration of tanks.

4.3. Another concern in the design of tanks and other combat vehicles is the growing threat of attacks from other than the traditional direct-fire weapons (from missile-armed helicopters, for example). The development of various forms of top attack is likely to demand a drastic reassessment of the distribution of armor protection.

4.4. A third need for new concepts is the emerging threat of attack by directed radiation weapons, which may make it necessary to depart from the direct-vision devices that have been used until now.

4.5. In the case of tanks and tank-like vehicles, the possibility of radically new and more effective configurations arises from the development of automatic loading systems for guns. This makes it practicable to depart from the configuration which was introduced with the design of the British A.10 E.1 tank and still embodied in the M1 and the Leopard 2.

4.6. Until now, tanks had to have a human loader for their main armament. This made it impossible to advance on the configuration devised by the designers of the A.10 E.1 tank 48 years ago (15). However, it is now possible not only to dispense with the human loader but also to operate the main armamant by remote control. In consequence, it is now possible to design tanks with basic features radially different from those of tanks designed in the past and in particular with externally mounted guns and ammunition completely separated from the crew for greater survivability.

4.7. There are also several other possibilities which did not exist before. One of them is the use of indirect vision devices, which offer entirely new opportunities for locating the crew within the hull where it can be better protected. Another is the use of liquid propellants for the main armament, which makes it possible to locate the projectiles separate from the propellant and, therefore, to devise for tanks a configuration of yet another, new kind. There is also the possibility of using articulated configurations which were seriously considered at USATACOM in the late fifties and which are now being reconsidered in Sweden (in a novel form that takes advantage of recent technological developments).

4.8. Some of these possibiities have already led to a number of novel designs, of which the Swedish articulated UDES XX 20 tank destroyer is one example. However, none of the new designs has advanced beyond experimental vehicles and none can be regarded as entirely satisfactory. It has not reached the stage where it could be accepted as a successor to the existing traditional designs.

4.9. It is imperative to use test bed vehicles to validate the new concepts and to make this work realistic.

4.10. Test bed vehicles are also essential to give the user a real opportunity to consider what is being proposed in place of the configurations with which he is familiar, and ultimately, of deciding whether he is prepared to accept whatever new configuration is being offered or not. A sound decision on this can hardly be expected of the user without him seeing the kind of vehicle that is being proposed for him to use.

4.11. Different possibilities exist in the case of other combat vehicles. For instance, the development of new, high-performance weapons of relatively light weight has made it possible to design vehicles which combine the ability of carrying infantrymen for dismounted action with some of the capabilities of tanks. However, precisely what kind of combat vehicle this might result in is not likely to be clear until a test bed has been designed and built. Nor will the user be able to see precisely what is involved in the operation of such a dual-purpose vehicle and to judge how it might be employed until a test bed vehicle is available for him for evaluation.

4.12. Other possibilities exist in the field of anti-tank guided missile vehicles which no longer need to use direct, line-of-sight guidance and whose configuration may be different, therefore, from that of the missile launcher vehicles built so far. There are also possibilities in the field of wheeled armored vehicles. In particular, there is a strong case for the development of an efficient, general-purpose wheeled armored carrier that would take advantage of the recent advance in component technology and advance beyond the existing wheeled combat vehicles.

5.0. BENEFITS OF TEST BED PROGRAMS

5.1. Several advantages of constructing test bed vehicles have been indicated already. However, the examples quoted do not cover all the benefits which accrue from it. It is advisable, therefore, to consider further aspects of the design and construction of test beds.

5.2. The most important aspect of the design and construction of test beds is they, "provide a better way to test hardware than any paper analysis, computer simulation, or intuitive judgement (16)." In other words, they allow new concepts to be judged more realistically than in any other way.

5.3. Testing of experimental vehicles is also bound to suggest improvements and changes to any new design concept which is unlikely to be perfect in its initial form, no matter how promising it might be. The consequent changes can be made relatively easily while the design is still at the stage of the test beds, because of their flexible, experimental nature, and in this way a new concept can be refined or optimised before a decision is made to develop it further and before the commitment to put it into production makes changes much more difficult and costly.

5.4. Thus, test bed vehicles serve to advance the engineering development of new concepts and they also form the basis of realistic judgments by the user. In addition, they allow the user to contribute to their more effective implementation. In particular, test beds provide the user with a timely opportunity to make criticisms and to suggest improvements from his point of view. The benefits of this are illustrated by the history of the Swedish S-tank. Its sighting system was changed radically after experimental prototypes were evaluated by the Swedish Army's Armor School which accepted the concept of the vehicle but rejected its original sighting system. The developers of the S-tank subsequently acknowledged that the new system which they were forced to develop represented a considerable improvement on their original, and the changes it involved could be incorporated relatively easily because the need for them was brought out before the design was frozen for production.

5.5. A systematic program of test bed design and construction also makes it possible to nurture economically at least one national combat vehicle design team, for which it can provide the necessary continuity of work and an opportunity to develop specialist experience. The continuity of work which test bed programs can provide is also conducive and indeed essential to the creation of an environment in which there is a continuity of thought being given to combat vehicle design and in which, therefore, new ideas are most likely to be generated.

5.6. None of these conditions exist when combat vehicles are developed by a discontinuous series of vehicle programs. (In fact, this mode of development leads to the disbanding, or at least to the running down, of design teams in between the programs, when there is little for them to do.) In consequence, transfer of experience suffers and every time a new program is started much of the necessary expertise has to be acquired afresh, at considerable cost in time and money.

5.7. Test bed programs can also provide a reservoir of new designs which can be put into production and service in the event of a national emergency much more quickly than any design which might be started in such circumstances from scratch. A clear illustration of the insurance value of test beds is provided by the history of the German Tiger, one of the most effective tanks of World War II. This heavy tank went into action only 15 months after its design was started in response to the threat posed to the German Army by the then newly encountered Soviet T-34 and KV tanks (17). The remarkably short development time was due not only to war-time pressure, but also the prior existence of a number of experimental heavy tanks, such as the DW 2, VK 3001 and VK 3601, which provided a ready basis for the design of the Tiger (18).

5.8. Another striking demonstration of the insurance value of test beds in relation to national emergencies is provided by the history of the US M3 medium tank. The pilot model was built in 1941, only nine months after its design was started. Again, this remarkably quick development was due to a large extent to the prior existence of a test bed vehicle, the T5E2 medium tank, on which the design of the M3, and in particular, its 75 mm gun installation could be based (19).

6.0. TEST BEDS BUILT IN DIFFERENT COUNTRIES

A number of recently built test bed vehicles have been mentioned already, in addition to earlier examples of their construction. However, there are further examples of their recent construction which are worth noting. This is most conveniently done by considering the leading combat vehicle developing countries in turn, with the exception of the Soviet Union for which no comparable information is available.

6.1. United Kingdom

The Military Vehicles and Engineering Establishment (MVEE) of the British Ministry of Defense has made extensive use of test bed vehicles to explore new concepts. It has used them with positive results, they formed the first step in the development of new vehicles which were ultimately fielded. They have had negative results when they proved originally promising concepts were not worth developing beyond a certain point, and saved possible misapplication of effort and money.

6.1.2. One of the MVEE test beds mentioned previously is the FV 4202, which proved a number of novel ideas subsequently incorporated in the current Chieftain battle tank. Another was the FV 4211, which proved Chobham special armor was a practical proposition, from the armor point of view. It then served as the basis of the design of the US M-1 and the latest British tank, the Challenger.

6.1.3. Prior to the construction of FV 4211, MVEE built a test bed vehicle called Contentious. This was built to explore the concept of a two-man battle tank with suspension controlled elevation, limited traverse turret and automatic loading. Work on Contentious was terminated around 1970, because it was not considered as attractive as other concepts which had emerged.

6.1.4. One of these new concepts was of a tank with an externally mounted gun. To explore it, MVEE built, in 1968, what was probably the first test bed ever to represent this concept. It was the basis of one of the three British design contributions to the Anglo-German battle tank program of 1972-76.

6.1.5. Concurrently with the construction of the test bed with an externally mounted gun, MVEE also developed a test bed to explore the possibility of greatly increasing armor protection by resorting to a turretless, or casemate, configuration with a semi-fixed gun mounting. This too formed the basis of one of the British contributions to the Anglo-German tank program of the mid-seventies. As it happens, the concept embodied in this test bed was not developed further at the time. But it has provided a potential basis for further development of this type of tank, which offers several of the advantages of the S-tank without some of the latter's disadvantages.

6.1.6. An earlier and very successful example of the test beds built by MVEE was the TV 15000, which was completed in 1964 (20). This vehicle served to establish the feasibility of a very light, aluminum-armored high-speed tank and led to the design of the current Scorpion light tank and its derivatives, including the Stormer, which was one of the contenders in the US Marine Corps Light Armored Vehicle (LAV) competition.

6.1.7. Another and even earlier test bed built by MVEE was the TV 1000, which was designed in 1956-57 to explore the concept of a wheeled tank. It was a large vehicle of 120 metric tons with six large tires. For the first time a wheeled armored vehicle maneuvered with skid steering. Work on TV 1000 was terminated in 1964, when the British Army decided to use tracks even for its light reconnaissance vehicles (1). However, TV 1000 demonstrated the advantages as well as the disadvantages of wheeled armored vehicles with skid steering. Given different policies on the part of the British Army, it might have served as the basis of a novel combat vehicle design. As it happens, it was left to the French Army to develop and field the first wheeled armored vehicle with skid steering, the AMX 10 RC.

6.1.8. More recently, in the mid-seventies, MVEE built a test bed to explore the concept of a relatively heavy mechanized infantry combat vehicle for MICV, which incorporated not only thick aluminum armor but, also, "Chobham" special armor. At the same time, and in spite of its weight of about 30 metric tons, this heavy MICV was expected to be highly mobile and was, therefore, provided with a hydropneumatic suspension. But, having had the opportunity to assess the concept of a heavy MICV the British Army rejected it. Instead they adopted the concept of a lighter infantry vehicle, which led to the MCV 80 (22). Although the earlier concept was rejected, experience acquired with the test bed contributed to the development of the MCV 80.

6.2. Federal Republic of Germany

6.2.1. Although the development of combat vehicles was only resumed in West Germany in the mid-fifties, it has provided several examples of the effective use of test beds to explore and to develop new design concepts.

6.2.2. Some of the earliest German examples of test beds are those built to explore the different configurations possible for infantry combat vehicles and to resolve questions about the location of the weapon station. Should it be manned by one or two men? In fact, three or four generations of test beds were built between 1960 and 1967 before the design of the Marder infantry vehicle was finally developed (22).

6.2.3. Another successful example of German test beds was the "experimental development", a vehicle built as a possible, more conventional alternative to the MBT-70 when the joint US-Germany development of the latter began to run into difficulties (24). When the joint program was terminated in 1970 the "experimental development" became the basis for the design of the current Leopard 2 battle tank.

6.2.4. German test beds, like the British, have also included purely exploratory vehicles. These served to investigate new concepts but only led to conclusions that they did not offer enough to justify further expenditure of effort and money. One such concept was that of a tank whose turret was stablized about all three axes. This led in 1966, to the construction and evaluation of a test bed, based on a modified Leopard 1 chassis, with negative results as it happens (24).

6.2.5. The outstanding example of the Germany exploratory test beds are the VT-1 experimental tanks built during the mid-seventies by the MaK Company. These casemate twin-gun vehicles were built to evaluate the effectiveness of a concept which combined some of the advantages of the S-tank with the evasive capabilities of an extremely agile tank and the ability to fire salvoes of two rounds to achieve greater hit probability. The concept of the VT-1 has not been accepted by the German Army, but the test beds related to it have become a source of valuable experience and some of their features provide a basis for further development.

6.3. France

6.3.1. France has produced several new combat vehicle concepts, and some notable examples of test beds. Concepts of French origin include tanks with oscillating, or trunion-mounted turrets, which has proved highly successful when embodies in the AMX 132 light tank. However, when the concept was explored further during the 1950's in a series of experimental heavy tanks, it was found to suffer from serious disadvantages. Its further development was discontinued and the experience with the test beds saved the French Army from misapplying its resources to the development of a battle tank with an oscillating turret.

6.3.2. Similarly, experience gained with test beds saved the French Army from wasting its resources on the further development of very light combat vehicles, exemplified by the two-man ELC which was armed either with a low-pressure 90 mm gun or two 30 mm automatic cannon. Vehicles of the ELC kind represented an attractive novel concept during the fifties when the emerging threat of shaped charge weapons appeared to herald the obsolescence of heavily armored vehicles. Trials with test bed vehicles proved that the concept of very light combat vehicles was far less attractive than it appeared at first, and work on it was discontinued around 1961 (25).

6.3.3 Nevertheless, the construction of the light combat vehicle test beds had a positive outcome in advancing the development of low pressure guns firing fin-stabilised, shaped charge projectiles. These 90 mm weapons have been successfully passed on to wheeled armored vehicles and have done much to increase their effectiveness. The first successful example of their use was in the French Panhard AML 90 light armored car, which was armed with the same 90 mm gun as the ELC tracked light combat vehicle. More recently several other wheeled armored vehicles have been armed with similar 90 mm guns which have been produced not only in France, but also in Belgium by Cockerill and in Brazil by Engesa.

6.3.4. A much more direct use of experience obtained with a test bed is illustrated by the AMX 10 RP. An AMX 10 armored infantry vehicle was converted from tracks to wheels but made to retain the skid steering of a tracked vehicle. Tests with it proved the feasibility of a wheeled armored vehicle with skid steering and led to the development of the AMX 10 RC, which is now the French Army's principal armored reconnaissance vehicle.

6.4. Sweden

6.4.1. Some of the best examples of the effective use of test beds are provided by the development of combat vehicles in Sweden and in particular, the development of the S-tank. The novel concepts embodied in that tank were first explored in a series of low-cost test beds. This greatly reduced the technical risks involved in the development of the S-tank and helped to keep its cost down.

6.4.2. The low-cost, stage-by-stage approach to new concepts is now being repeated in the development of a novel articulated tank destroyer armed with a 120 mm gun, the UDES XX 20. The development of this vehicle started with the construction of a reduced scale test bed, based on the chassis of the light, articulated BV 206 carrier, which proved the new automotive features of the concept. This was accompanied by the construction of another test bed, which consisted of a 105 mm tank with an enlarged chamber mounted on the chassis of a Marder mechanized infantry combat vehicle, which proved the feasibility of firing a 120 mm tank gun from a relatively light vehicle of about 20 metric tons. After these basic issues were resolved with the two test beds, the tank destroyer program advanced to the construction of the UDES XX 20 test bed, which is close in several respects to the vehicle that might be fielded. However, the primary purpose of the UDES XX 20 is to develop the installation of the 120 mm gun and its control system, and also to develop the elaborate automatic loading system associated with this concept. Only when all this has been successfully accomplished will the decision be made, whether or not to proceed with the articulated tank destroyer.

6.5. United States

6.5.1. The US Army Ordnance Tank-Automotive Command, or OTAC as it then was, had in the past built many experimental vehicles which would now be called test beds. An early example of this was the T69 tank built during the early 1950s. This represented the first attempt by OTAC to develop an oscillating turret with an automatic loading system. It became the forerunner of several other designs incorporating an oscillating turret with an automatic loader. One outcome of those designs was the concept of a low frontal area turret, first put into practice in a more conventional, non-oscillating turret mounted on one of the test vehicles of the the XM66 tank program, and eventually led to the turret of the M60A2.

6.5.2 Other examples of early test bed vehicles include the T92 light tank, which put to test the then novel concept of a cleft turret as well as a swing-arm semi-automatic loading system for its 76 mm gun. A particularly noteworthy example of the experimental vehicles built during the late 1950s was the T95 medium tank. This served to test several new concepts, including a rigidly-mounted smooth-bore gun firing APSDS projectiles, an OPTRAC light beam rangefinder, and an adjustable hydropneumatic suspension. Several of the results obtained with the T95 were negative, in the short or in the long term. They were valuable. For instance, the TG95 demonstrated conclusively the rigid mounting of guns without conventional recoil systems was not worth pursuing. On the other hand, although the performance of the smooth-bore guns firing fin-stabilized APSDS which were mounted in the T95 was disappointing, they have since become accepted as the most effective type of tank main armament. Similarly, the use of the hydropneumatic suspension in the T95 has led to successful suspensions of this type.

6.5.3. Although the T95 failed to become the prototype of a new medium tank, it was a valuable test bed for several new concepts. If some of the unsatisfactory features originally incorporated in its design had been eliminated, and if the rest of it had been developed further, the T95 might have led to the prototype of a superior alternative to the M60 tank.

6.5.4. Instead, development effort was redirected during the early 1960s to the entirely new design represented by the MBT-70. This was preceded by the construction of a test bed vehicle embodying the concept of locating the driver in the turret, which was incorporated in the MBT-70. However, several other features of the MBT-70 were not evaluated in test bed vehicles prior to the decision to develop it. As a result, many of the problems associated with them could only be identified after the prototypes of the MBT-70 were built. This aggravated the difficulties that faced the MBT-70 program and then its follow-on, the XM803 program, and contributed to a considerable extent to both programs being abandoned.

6.5.5. The outstanding example of a test bed constructed in recent years is represented by the High Mobility/Agility, or HIMAG, vehicle. This was built as part of the Armored Combat Vehicle Technology Program to resolve a number of basic questions about the degree of mobility and agility attainable and effective in the present state of combat vehicle technology. It was also intended to be used for assessing the effectiveness of a gun with an automatic loading system capable of high rates of fire, and for evaluating several different gun fire control system configurations. In principle, the HIMAG test bed provided a basis for decisions about several important aspects of the design of future combat vehicles.

6.5.6. The HIMAG test bed was followed by the construction of the High Survivability Test Vehicle - Lightweight, or HSTV-L. This test bed vehicle was intended to complement the HIMAG test bed by incorporating additional features that could not be included in the latter. The HSTV-L also came to be regarded, albeit incorrectly, as a prototype for the Mobile Protected Weapon System (MPWS) required by the US Marine Corps. As a prototype the HSTV-L left much to be desired, but as test bed it served a useful purpose and it demonstrated at least one possible solution to the Army's and the Marine Corps' need for a lightweight combat vehicle with an effective gun.

6.5.7. The contract for the latest US test bed program has been awarded to the Land Systems Division of General Dynamics Corporation. It is aimed at a novel battle tank configuration with an externally mounted gun. The program should provide an urgently needed opportunity to explore some of the new possibilities in tank design, including greatly increased protection for the new, and indirect viewing through electro-optical sight systems, also the remote control of an externally mounted gun and its automatic loading. However, the program involves the construction of only one test bed and this can not be used to explore more than a limited range of possibilities. In fact, due to limited program funds, the automotive components of the test bed will be the same as those of the M-1 tank. The test bed represents only one of several different configurations or ways of integrating components. There is a clear need, therefore, a greater number of different test beds to explore and to evaluate the new possibilities in the design of tanks and other combat vehicles.

7.0. CONCLUSION

7.1. The study of test beds shows that they perform an important function in the development of combat vehicles, and also in the exploration and evaluation of new design concepts. Test beds have a specially important role to play at the present time because of the demand for new concepts created by the changes in the situation concerning combat vehicles. These changes include: the increasing lethality of the threat facing combat vehicles, additional directions from which they might be attacked, possible contamination of the battlefield environment, degradation of visibility due to obsuration, and changes in the potential threats of operation. All this leads to a growing demand for a departure from the traditional design practices and for considering instead new and unconventional considerations.

7.2 Whatever the new concepts might be, their feasibility and effectiveness need to be clearly established. This obviously can not be done on the basis of claims made by their proponents, no matter how well intentioned such claims might be. Neither can the new configurations be adequately assessed by the subjective judgment of other individuals or by analytical combat modes, as past experience has demonstrated.

7.3. To assess new combat vehicle concepts adequately it is necessary to take advantage of test beds. In fact, test beds provide the only method of demonstrating new concepts clearly, and of allowing them to be evaluated without ambiguities.

7.4. Test beds are an essential means of validating new concepts, and of forming a sound basis for future combat vehicle develop programs.

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